HUNGRY CITIES PARTNERSHIP

Discussion Papers

FEBRUARY 2018

NO. 14
THE IMPACT OF PROXIMITY TO WET MARKETS AND SUPERMARKETS ON HOUSEHOLD DIETARY DIVERSITY IN NANJING CITY, CHINA

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Abstract

Existing studies suggest that despite the proliferation of supermarkets, traditional wet markets have persisted in many countries and have been playing an important role in people's daily food access. Yet, studies investigating the issue of food access and its influences on food security have mainly focused on food deserts and the proximity to supermarkets, with limited focus on wet markets and other food outlets. This study investigates the influence of the proximity to wet markets and supermarkets on urban household dietary diversity in Nanjing. Based on the data collected through a citywide survey in 2015 and the map data of wet markets and supermarkets, the Poisson regression model was deployed to examine the correlations between geographical proximity to supermarkets and wet markets and household dietary diversity. The results show that the coefficients for the distance to the nearest wet market are not statistically significant. Although the coefficients for the distance to nearest supermarket are statistically significant, they were too minor to be of practical importance. We argue, however, that the insignificant correlations reflect exactly the high physical accessibility to food outlets and the extensive spatially dense food supply network constituted by wet markets, supermarkets and small food stores in Nanjing. This is verified by the survey data that more than 90% of households purchased fresh food items within their neighbourhoods or in walking distance. In addition to the densely distributed food outlets, various other factors contributed to the non-significant influence of the distance to the nearest wet market and supermarket, including the many small food stores within or close to residential communities, the prevalence of three-generation extended households and high household income. This study highlights the importance of allowing mixed land use for food outlets with residential land and integrating wet markets into urban infrastructure planning.

Keywords

proximity to food outlets, dietary diversity, food access, food security, food environment

This is the 14th discussion paper in a series published by the Hungry Cities Partnership (HCP), an international research project examining food security and inclusive growth in cities in the Global South. The five-year collaborative project aims to understand how cities in the Global South will manage the food security challenges arising from rapid urbanization and the transformation of urban food systems. The Partnership is funded by the Social Sciences and Humanities Research Council of Canada (SSHRC) and the International Development Research Centre (IDRC) through the International Partnerships for Sustainable Societies (IPaSS) Program. Thanks to Bronwen Dachs, Maria Salamone and Cameron McCordic for their assistance.

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Introduction

The relationship between household dietary diversity and access to food markets has been investigated in several studies. Some suggest that an increase in distance to food markets may decrease dietary diversity and increase food insecurity (Downing and Laraia 2016, Liu et al 2014, Matchaya and Chilonda 2012). Restricted access to supermarkets, in particular, can reduce healthy food consumption as (Michimi and Wimberly 2010). In contrast, other studies maintain that there is no causal linkage between access to food markets and dietary diversity. A study in Michigan, USA, for example, found that physical distance to food outlets providing healthy food did not significantly influence fruit and vegetable consumption (Sadler et al 2013) Another study suggests that it is the price of food in supermarkets, rather than the physical distance to market, that most influences the consumption of fruits and vegetables (Aggarwal et al 2014). This implies that the direct cost of food is a much more important factor than indirect factors such as physical distance and travel cost.

Another group of researchers suggests that the potential impact of distance on dietary diversity is mediated by other factors. Even when supermarkets are physically present in low-income urban areas, for example, this does not necessarily improve dietary diversity since they tend to carry a less healthy and diverse range of foods (Battersby and Crush 2014). A study in the US found that an increase in the distance to a supermarket decreases the odds of fruit and vegetable consumption in metropolitan areas but has no impact in non-metropolitan areas (Michimi and Wimberly 2010). An analysis of data from 21 African countries found that distance to the nearest road (and therefore transaction costs for food purchase) had a significantly negative impact on fruit and vegetable consumption, but no significant effect on animal-source food consumption (Ickowitz et al 2014). The impact of improved locational access to food markets also tends to vary with household income with low-income households benefitting more than wealthier groups (Pearson and Wilson 2013). Thus, while distance to food outlets does seem to be an important variable in household food consumption, a consensus has yet to be reached on its influence on household food security (Ver Ploeg et al 2015).

There is a widespread assumption that the one-stop shopping associated with supermarkets is less costly than multi-stop shopping and therefore more attractive to consumers. However, despite the proliferation of large supermarkets and hypermarkets, the multi-stop shopping model still prevails in much of Asia (Goldman et al 2002). Chinese consumers value the freshness of food and prefer to buy small amounts of fresh vegetables on a daily basis rather than storing vegetables for a longer period (Zhang and Pan 2013). The main advantages of wet markets over supermarkets are the freshness and affordability of food, regardless of supermarket penetration (Gorton et al 2011, Zhang and Pan 2013). Food purchasing is also shaped by the practice of shopping for different foods at different outlets; for instance, buying perishable food in traditional wet markets and processed food in supermarkets. Multi-stop shopping at different forms of retail outlet means that dietary diversity and household food security cannot be seen as the outcome of distance to a single food purchasing location.

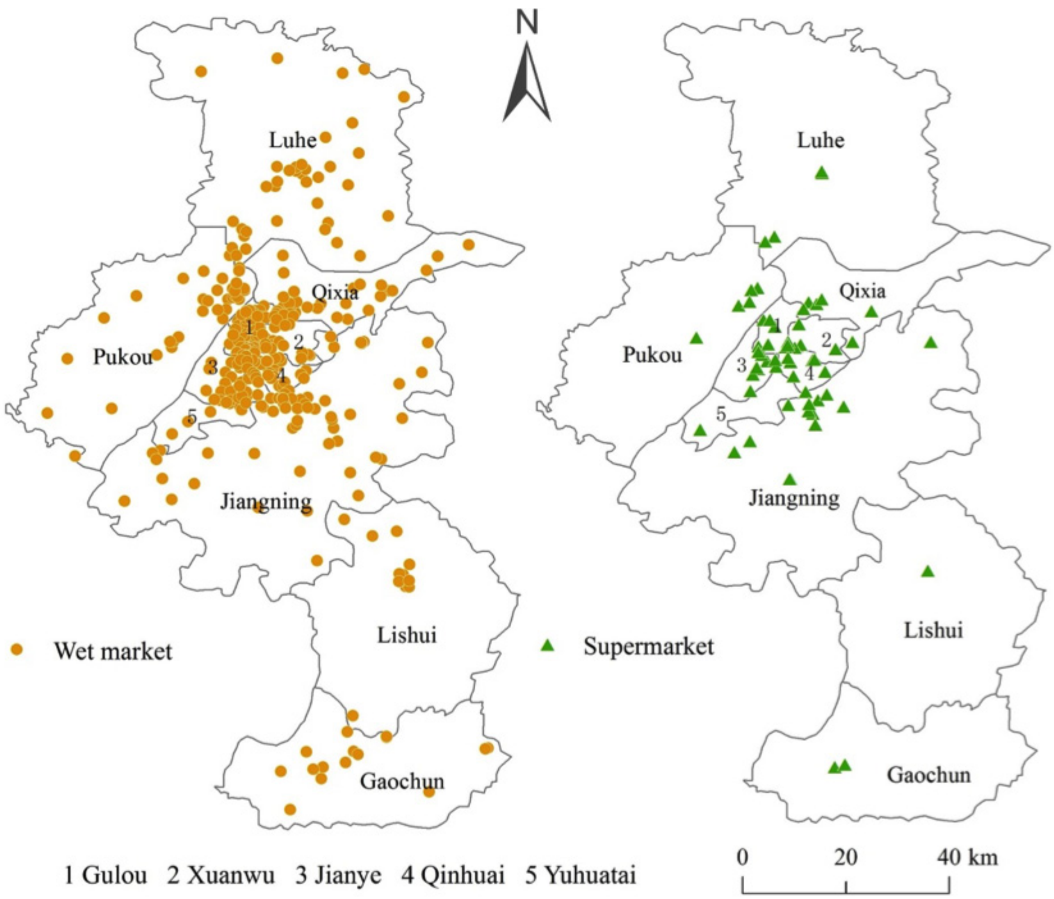
Previous studies have focused on the impact of proximity to supermarkets on food security and neglected the influence of proximity to wet markets. Moreover, most studies of food security in China have focused on national or regional-level food supply with few studies paying attention to household-level food security in urban areas. Quantitative analysis of the relationship between physical access to food outlets and household dietary diversity of China is absent. To bridge this gap, this study aims to examine the relationship between proximity to wet markets and supermarkets and urban household dietary diversity.

Wet Markets and Supermarkets in Nanjing

Despite the proliferation of supermarket chains since the 1990s, wet markets remain the most prevalent food outlet in urban China. They specialize principally in fresh vegetables, fruit, livestock products, aquatic products (such as live fish and shrimp), poultry products, and staple foods (such as rice and cereal flours). The Chinese government launched a program in the early 2000s to convert wet markets into supermarkets (known as *nong gai chao* in Chinese) in many large cities (Hu et al 2004, Wang and Shi 2012). However, this project failed in many cities including in Nanjing (Zhang and Pan 2013) and wet markets remain dominant in fresh food retailing (Bai et al 2008, Zhang and Pan 2013). In Dalian, wet markets are the main fresh food source for almost half (49%) of urban households (Maruyama and Wu 2014), and in Shanghai, they are the source of fresh meat and vegetables for 76% and 59% of households respectively (Goldman 2000). Wet markets carry a variety of fresh foods at low cost, providing a price advantage over supermarkets (Zhang and Pan 2013).

In Nanjing, wet markets have conventionally been the dominant outlet for healthy food. There were 351 wet markets in Nanjing in 2015, or about one wet market per 19,100 people on average (excluding rural households) or one per 23,464 people (including rural households). The overall density of wet markets is one per 2.1km^2. In contrast, there are 63 supermarkets in Nanjing, operated by eight companies. The major chains include Suguo (38 supermarkets), BHG (8), Carrefour (5), and Wal-Mart (5). Figure 1 shows the location of wet markets and supermarkets across Nanjing's 11 districts.

FIGURE 1: Location of Wet Markets and Supermarkets in Nanjing City



Source: Data from BaiduMap (map.baidu.com)

Nanjing's upgraded wet markets are somewhat different from traditional Chinese wet markets. Traditionally, wet markets were housed in temporary sheds or in the open air. Most wet markets in Nanjing are housed in permanent buildings and stalls selling meat are usually equipped with refrigeration facilities (Zhang and Pan 2013). Nanjing has had no open air wet market or wet markets in temporary sheds since the end of 2014 (Nanjing Municipal Government 2013). The space of a wet market is usually divided into small stalls that are rented and operated by private individual food vendors.

Wet markets in Nanjing fall under a two-tier management system. The first tier is the Nanjing Municipal Government, which owns the city's wet markets and regulates their distribution (Nanjing Municipal Government 2016). In 2003, the government stipulated that a new wet market should be established whenever a new residential community of over 50,000m^2 was developed (Nanjing Municipal Government 2003b). In 2011, a new requirement specified that a wet market should be established for every 25,000 persons in built areas of over 2,000m^2 (Nanjing Municipal Government 2011). The second management tier means that wet markets are operated and managed either by state-owned or private companies or offices (hereafter, the management body). The management body is selected by the district-level governments and is responsible for the safety and sanitation of the wet market, stall lease management, facility maintenance and food safety monitoring (Nanjing Municipal Government 2016). The vendors renting the stalls in wet markets buy food from wholesale markets, distribution centres or other sources and pay a stall rent and fee to the management body.

Supermarkets are another important food source for households in Nanjing. Table 1 shows the distribution of wet markets and supermarkets in each of the 11 districts. It demonstrates that, with only 63 supermarkets selling vegetables and fruit, the number of supermarkets is much smaller than the number of wet markets in every district. Unlike wet markets, there is no statutory requirement for supermarket development by the size of population of an area. The variation of population per wet market across the districts is much smaller than that of supermarkets. However, in 2011, the Nanjing Municipal Government required that no less than 20% of an existing supermarket's retail area (and 30% for newly-opened supermarkets) be dedicated to live and fresh agricultural produce (Nanjing Municipal Government 2011).

TABLE 1: Wet Markets, Supermarkets and Population in Nanjing

District	Population	No. of wet markets	No. of supermarkets	Population per wet market	Population per supermarket
Xuanwu	652,400	21	6	31,067	108,733
Qinghuai	1,022,400	27	7	37,867	146,057
Jianye	454,500	25	8	18,180	56,813
Gulou	1,275,600	54	6	23,622	212,600
Pukou	749,400	37	6	20,254	124,900
Qixia	679,800	38	7	17,889	97,114
Yuhuatai	426,900	27	3	15,811	142,300
Jiangning	1,191,400	56	14	21,275	85,100
Liuhe	934,400	37	4	25,254	233,600
Lishui	424,400	13	1	32,646	424,400
Gaochun	424,700	16	1	26,544	424,700
Total	8,235,900	278	42	29,626	196,093

Source: Population data from Nanjing Municipal Bureau of Statistics (2016)

Methodology

Household Dietary Diversity

The household data used in this paper is extracted from the urban household baseline food security survey in Nanjing conducted in July 2015, and funded by the Hungry City Partnership. The total sample size was 1,210 households, randomly selected from 972 urban communities in all 11 districts of Nanjing. The survey was conducted by undergraduate and graduate student enumerators from Nanjing University using digital surveys on android tablets. The data was then uploaded and synthesized on the online Ona database. Household dietary diversity was measured by the Household Dietary Diversity Score (HDDS) (Swindale and Bilinsky 2006). Food items consumed in the 24 hours prior to the survey were grouped into the following 12 food groups: a) cereals; b) roots and tubers; c) vegetables; d) fruit; e) meat, poultry and offal; f) eggs; g) fish and seafood; h) pulses, legumes and nuts; i) milk and milk products; j) oil and fats; k) sugar and honey; and l) other foods. The HDDS is calculated from the number of food groups eaten from and ranges in value from 0 to 12, where the higher the score the greater the diversity in the household diet.

Tables 2 and 3 show the statistical summary of the HDDS in Nanjing and household food consumption by food groups. The dietary diversity of Nanjing households is relatively high with a mean HDDS of 7.83. Some 60% of households scored between 7 and 12 (i.e. eating foodstuffs from between 7 and 12 of the food groups). Over 80% had a score of 6 or more and only 17% had a score of 5 or less. By way of comparison, the mean HDDS of other cities in the Hungry Cities Partnership project was significantly lower (Table 3).

TABLE 2: Frequency Distribution of HDDS in Nanjing

	No.	%	Cumulative %
1	7	0.6	0.6
2	10	0.8	1.4
3	43	3.6	5.0
4	61	5.0	10.0
5	85	7.0	17.1
6	117	9.7	26.7
7	148	12.3	39.0
8	213	17.6	56.6
9	219	18.1	74.8
10	164	13.6	88.3
11	110	9.1	97.4
12	31	2.6	100.0
Total	1,208	100.0	

TABLE 3: Comparison of HDDS Scores in HCP Cities

	Household Dietary Diversity Score		
	Mean	% ≤5	n
Nanjing	7.83	17.1	1,208
Cape Town	6.75	29.3	2,504
Nairobi	6.04	40.9	1,414
Mexico City	5.85	49.8	1,210
Bangalore	5.37	59.1	1,878
Kingston	4.51	70.6	698
Maputo	4.14	76.2	2,071
Windhoek	3.21	89.1	855

There were notable differences in the frequency of consumption of different food groups (Table 4). Cereals (including wheat, rice and other grains) ranked first with about 98% of households consuming cereals. The vegetable and fruit groups ranked second and third respectively with percentages of about 97% and 80%. The roots and tubers group ranked lowest with a proportion of about 34%, slightly lower than fish and seafood at 37%.

Wet markets and supermarkets are the two most frequently used food sources in Nanjing (Si et al 2016). Almost 93% and 87% of households buy food from wet markets and supermarkets, respectively (Table 5). However, there is a notable difference between the purchasing frequencies at wet markets and supermarkets. About 70% of households use wet markets at least five days a week, while the number for supermarkets is only about 17%.

Network Distance to Food Markets

Household locations were collected by the enumerators using android tablets with built-in GPS, with a positioning accuracy of 15 metres. The location data of wet markets and supermarkets was calculated from the BaiduMap (map.baidu.com) – the most widely used online map service in China. Other outlets, such as small stores and mobile vendors, were not included in the analysis because of the logistical difficulty of plotting their GPS locations. Because the GPS in tablets is based on the WGS84 coordinate system but the BaiduMap uses the BD09 coordinate system, the GPS coordinates of the households' location were converted into BD09 coordinates before analysis.

The network distance from households to wet markets and supermarkets was calculated using Route Matrix API v2.0 Beta of BaiduMap. The Route Matrix API v2.0 Beta provides four transport

TABLE 4: Frequency Distribution of Consumption of Food Groups

Food item	No. of households	% of households
Cereals	1,179	97.6
Vegetables	1,171	96.9
Fruits	964	79.8
Meat, poultry, offal	952	78.8
Eggs	949	78.6
Oil and fats	937	77.6
Milk and milk products	791	65.5
Pulses, legumes, nuts	539	44.6
Sugar or honey	477	39.5
Fish and seafood	450	37.3
Root and tubers	406	33.6
Other foods	645	53.4

TABLE 5: Frequency of Patronage of Wet Markets and Supermarkets

Frequency (at least)	Supermarkets		Wet markets	
	No. of households	%	No. of households	%
Five days a week	176	16.7	843	75.2
Once a week	673	63.9	248	22.1
Once a month	187	17.8	26	2.3
Once in six months	16	1.5	3	0.3
Once a year	1	0.1	1	0.1
Total	1,053	100.0	1,121	100.00

modes for network distance calculation: walking, by car, by public transport and by bicycle. This study chose the pedestrian mode because walking and bicycling are the two principal transport modes for food shopping and, of these, walking is the most important. The survey found that about 90% of households bought their primary food within walking distance of their homes more than five times a week. The percentage of respondents who bought fresh vegetable, fruit and pork within walking distance were 93% (N=988), 92% (N=974) and 92% (N=957), respectively. Another survey conducted in Nanjing in 2012 found that 61%, 20% and 17% of elderly Nanjing residents went shopping by walking, bicycle (including electric bicycle), and public transportation, respectively (Feng and Yang 2015). The figures for young adults were 40%, 37% and 11% for young adults. We then calculated the walking distance from each household residence to the nearest wet market and the nearest supermarket.

Dependent and Independent Variables

Table 6 presents the definitions, expected signs, and summary statistics of variables used in this paper. The HDDS was used as the dependent variable. The primary factors seen as potentially influencing household dietary diversity were as follows:

1) Proximity: The distance to the nearest wet market and supermarket was used to reflect the proximity of a household to food stores. They are represented by independent variables *DTWM* and *DTSM*. The variable *DTNM* was generated by taking the minimum value of the variables *DTWM* and *DTSM* for each household, i.e. the distance to the nearest supermarket or wet market. Assuming that there is a negative correlation between physical proximity to food stores and household dietary diversity (Liu et al 2014, Michimi and Wimberly 2010), the coefficients for the variables *DTWM*, *DTSM* and *DTNM* are hypothesized as negative.

2) Household head: The demographic characteristics of household heads have been considered possible determinants of household dietary diversity in previous studies (Gustat et al 2015, Mbwana et al 2016, Workicho et al 2016). The second set of independent variables – *HHA, HHE, HHM* and *HHG* – therefore represent the age, education level, marital status and gender of the household head, with positive coefficients (Table 6).

3) Household size: A third set of variables relates to household size or *HHS*. The value of *HHS* is the number of household members. A set of dummy variables was used for household size, i.e. *HHS2, HHS3, HHS4, HHS5, HHS6, HHS7, HHS8* and *HHS9*. As larger households tend to consume more diverse food items (Liu 2017), they are expected to have a higher HDDS. The *HHS* and the 8 dummy variables are hypothesized to have positive coefficients.

4) Household structure: Households were categorized into five types: female-centred, male-centred, nuclear, extended and other. The female-centred household has a female head with no male spouse/partner in the household but may include relatives, children and friends. Male-centred households have no female spouse/partner. Nuclear households have a husband and wife (male/female partner) with or without children. Extended households refer to those with a male husband/partner and female wife/partner plus children and relatives. In China, the extended household usually includes grandparents, which influences family-based food consumption and could increase food diversity (Liu et al 2014). In the Nanjing survey, nuclear households were most common (57% of households), followed by extended households (29%), female-centred (7%) and male-centred (6%). The variable *SEXC* represents female-centred or male-centred households, and *EXTD* represents extended households. The variable *EXTD* is hypothesized to have positive coefficients.

5) Household income: Data on household monthly income was collected in the household survey and for the purposes of this analysis into income terciles. *HHIM* and *HHIH* represent the middle

and high income terciles. As household income is positively correlated with dietary diversity in other studies (Gustat et al 2015, Liu et al 2014), the variables *HHIM* and *HHIH* were projected to have positive coefficients.

6) Housing type: Type of housing is generally considered to be correlated with household food security (Guo 2011, Ver Ploeg 2010). The variable *HOUSE* was used to reflect the housing type of each household. In the case of Nanjing, a flat or apartment is the dominant housing type, accounting for 82% of all the surveyed households. The traditional dwelling is the second most common housing type, accounting for 13%. House and other types account for 3% and 2%, respectively. The variable *HOUSE* is assumed to have positive coefficients and is a dummy variable whose value is 1 for those households living in a house or townhouse.

7) Urban agriculture: Some households living on the urban periphery engage in urban agriculture, with about 18% of households growing some of their own food. The variable *CROPPING* was used to reflect those households growing food. The variable was hypothesized to have positive coefficients.

TABLE 6: Dependent and Independent Variables

Variable	Definition	Expected sign	Mean	Standard deviation
HDDS	Dependent variable, Household Dietary Diversity Score with value ranging from 0 to 12		7.83	2.31
DTWM	Distance to the nearest wet market (100 metres)	-	15.16	16.31
DTSM	Distance to the nearest supermarket (100 metres)	-	40.53	42.16
DTNM	Distance to the nearest wet market or supermarket (100 metres)	-	13.09	12.86
HHE	Household head highest level of education, HHE=1 for no formal schooling, HHE=0 for otherwise	-	0.05	0.21
HHM	Household head marital status, HHM=1 for unmarried, 0 for otherwise	-	0.02	0.15
HHG	Household head gender, HHS=1 for male, 0 for otherwise	-	0.74	0.44
HHA	Household head age (year)	-	53.57	15.72
HHS	Household size (person)	+	3.13	1.37
HHS2	Dummy variable for household size, HHS2=1 for 2 persons, 0 for otherwise	+	0.31	0.46
HHS3	Dummy variable for household size, HHS3=1 for 3 persons, 0 for otherwise	+	0.27	0.44
HHS4	Dummy variable for household size, HHS4=1 for 4 persons, 0 for otherwise	+	0.12	0.32
HHS5	Dummy variable for household size, HHS5=1 for 5 persons, 0 for otherwise	+	0.18	0.39
HHS6	Dummy variable for household size, HHS6=1 for 6 persons, 0 for otherwise	+	0.03	0.17
HHS7	Dummy variable for household size, HHS7=1 for 7 persons, 0 for otherwise	+	0.00	0.05
HHS8	Dummy variable for household size, HHS8=1 for 8 persons, 0 for otherwise	+	0.00	0.06
HHS9	Dummy variable for household size, HHS9=9 for no less than 9 persons, 0 for otherwise	+	0.00	0.03
EXTD	Dummy variable for extended family, EXTD=1 for extended family, 0 for otherwise	+	0.27	0.45

SEXC	Dummy variable for male-centred or female-centred family, SEXC=1 for male-centred or female-centred family, 0 for otherwise	-	0.12	0.33
HHIM	Dummy variable for net household income tercile, HHIM=1 for middle income (4,501-8,200 Yuan monthly), 0 for otherwise	+	0.31	0.46
HHIH	Dummy variable for net household income Tercile, HHIH =1 for high income (more than 8,200 Yuan monthly), 0 for otherwise	+	0.33	0.47
HOUSE	Dummy variable for dwelling type, HOUSE=1 for house or town house, 0 for otherwise	+	0.01	0.11
CROPPING	Dummy variable for growing food, CROPPING=1 for household growing its own food, 0 for otherwise	+	0.18	0.38

Regression Model

A Poisson model was used in this study to investigate the influence of physical access to food stores on household dietary diversity. The value of the dependent variable *HDDS* varies from 1 to 12, which is a count variable. The value of *HDDS* is assumed to have a Poisson distribution with expectation μ; for independent variables *Xi*, the Poisson regression model for expected counts can be specified as an exponential function (Rabe-Hesketh and Skrondal 2012). For the dependent variable *HDDS*, the Poisson regression model is as follows:

$$\mu_i = E(HDDS_i | X_i) = \exp(\beta_0 + \beta_i X_i)$$

Where *HDDS* is the HDDS of household *i*, *Xi* refers to the vector of independent variables, β_0 and β_i are the constant and the coefficient vector for independent variables, respectively. The alternative log-linear model can be written as:

$$\ln(\mu_i) = \exp(\beta_0 + \beta_i X_i)$$

Both the variable *HHS* and the dummy variable set including *HHS2-HHS9* are used to reflect the size of a household in terms of continuous and discrete numbers, respectively. Because of the one-child policy enforced in China between 1979 and 2015, nuclear households generally have a small household size. Thus, it is not reasonable for the model to include both the variable *HHS* and the dummy variable for household size. Households with more than 4 or 5 persons are also usually extended households. The independent variable *HHS* representing household size therefore reflects almost the same information as the dummy variable *EXTD* when the value of variable HHS is more than 4 or 5 persons, which makes it inappropriate to include both the variable *HHS* and the dummy variable *EXTD* in the analysis. Therefore, this study considered three different models including different sets of independent variables reflecting household size (variable *HHS* or dummy variables *HHS2-HHS9*) and household type (dummy variable *EXTD*) (see Model I, Model II and Model III in Table 7).

To investigate the relationship between dietary diversity and proximity to the nearest supermarket or wet market, the variable *DTSM* and *DTWM* in Model I, Model II and Model III were replaced by the variable *DTNM*. As a result, Model IV, Model V and Model VI were generated and calculated i.e. Model IV was built from Model I by replacing the variable *DTSM* and *DTWM* with variable *DTNM*. The same holds for Model V and Model VI. For the estimated results for Model IV, Model V and Model VI, see Table 7.

Models of Dietary Diversity

The models with different sets of independent variables are presented in Table 7. Model III includes those variables reflecting household structure and excludes those reflecting household size. Models I and II include those variables reflecting household size and exclude those reflecting household structure. Model I uses the variable *HHS* to measure household size rather than the set of dummy variables *HHS2-9*, while Model II used the set of dummy variable *HHS2-9* rather than the variable *HHS*. The three models perform satisfactorily in terms of goodness of fit. All six models are significant at the 1% level. The signs for all the explanatory variables are consistent with expectations.

Table 6 presented the value of AIC and BIC, which indicates that the smaller AIC or BIC, the better the model (Rabe-Hesketh and Skrondal 2012). Model I has the smallest values of both AIC and BIC, suggesting that it is statistically superior to the other five models. As there are no major differences in AIC and BIC in the six models, the estimated results of the other five models are also worthy of being analysed as they include variables different from Model I.

The results of this analysis indicate that physical access to wet markets is not a predictor of household dietary diversity in Nanjing. The signs of the estimated coefficients for the variable *DTWM* are consistent with expectation, but the estimated coefficients are statistically insignificant, which suggests that the distance to the nearest wet market is not a determinant of HDDS. However, the suppression effect caused by a "third variable" (X2, suppressor) could render the relationship between independent variable (X1) and dependent variable

TABLE 7: Estimated Results of Poisson Model for Household Dietary Diversity

Variable	Model I	Model II	Model III	Model IV	Model V	Model VI
DTWM	-0.0003	-0.0002	-0.0003			
DTSM	-0.0006**	-0.0006**	-0.0006**			
DTNM				-0.0006	-0.0004	-0.0005
HHE	-0.1936*	-0.1754*	-0.1974*	-0.2004*	-0.1827*	-0.2042*
HHM	-0.2117**	-0.1446	-0.2161**	-0.2119**	-0.1477	-0.2209**
HHG	-0.0485	-0.0593	-0.0493	-0.0525	-0.0628***	-0.0512
HHA	0.0010	0.0011	0.0007	0.0011	0.0012	0.0009
HHS	0.0307*			0.0306*		
HHS2		0.1554**			0.1526**	
HHS3		0.1846*			0.1788*	
HHS4		0.1867*			0.1838*	
HHS5		0.2683*			0.2649*	
HHS6		0.2106**			0.2074**	
HHS7		-0.5423			-0.5463	
HHS8		0.1987			0.1934	
HHS9		0.0240			0.0115	
EXTD			0.0825*			0.0845*
SEXC			-0.0406			-0.0325
HHIM	0.1235*	0.1082*	0.1226*	0.1300*	0.1154*	0.1302*
HHIH	0.0999*	0.0895*	0.1062*	0.1113*	0.1019*	0.1184*
HOUSE	0.1867***	0.1870***	0.1856***	0.1927**	0.1934**	0.1911**
CROPPING	0.0313	0.0240	0.0295	0.0138	0.0061	0.0121
Constant	1.9275*	1.8514*	2.0169*	1.8971*	1.8237*	1.9831*
N	858	858	860	858	858	860
LR chi^2	75.9900*	87.6000*	76.8700*	71.4600	82.8800	72.3800
Pseudo R^2	0.0194	0.0224	0.0196	0.0182	0.0211	0.0184
Log likelihood	-1921.5824	-1915.7798	-1925.2048	-1923.8491	-1918.1398	-1927.4492
AIC	3867.1650	3869.5600	3876.4100	3869.6980	3872.2800	3878.8980
BIC	3924.2200	3959.8970	3938.2500	3921.9990	3957.8630	3935.9820

Note: * denotes significant at 1%-level, ** significant at 5%-level, and *** significant at 10%-level

(Y) insignificant (Wen et al 2012), smaller, or of opposite sign (Cheung and Lau 2008, Cohen et al 2013). Households farthest from wet markets could have decreased odds of buying food from wet markets but increased probability of buying food from small food stores, so that purchase of food from small food stores could be a suppressor (the "third variable" X2). Thus, a new variable *SFSA* was generated, which refers to whether or not households buy food in small food stores. Following the testing procedure developed by Wen and Ye (2014), the possible mediation and suppression effects of the variable *SFSA* were tested. The results indicate that there are no mediation or suppression effects for the variables *DTWM* and *SFSA*. This confirms that distance to wet markets is not a predictor or determinant of urban household dietary diversity in Nanjing.

The estimation results also suggest that physical access to supermarkets has a limited influence on household dietary diversity. The estimated coefficients of the variable *DTSM* of Models I, II and III are all statistically significant at the 5% level and the signs of the estimated coefficients are consistent with expectations. However, all the coefficients of the variable *DTSM* in Models I, II and III are quite small (Table 7). The factor by which the expected count changes can be calculated is Exp(β) for a unit change in the explanatory variable, keeping other independent variables constant (Long and Freese 2001). According to the estimated coefficients in Models I, II and III, for a unit increase of 100 metres in the variable *DTSM* (distance to the nearest supermarket), the expected value of a household's HDDS decreases by a factor of 0.9994 or 0.1%, which is a very small magnitude of change. Even for an increase of 10 units (1,000 metres) in the variable *DTSM*, the expected value of a household's HDDS decreases by a factor of only 0.9934, or less than 1%. The test results also indicate that there is no mediation and suppression effect for the variable *DTSM* and variable *SFSA*. Therefore, the influence of the proximity to a supermarket on HDDS is also nearly negligible, regardless of the statistical significance of the estimated coefficients.

The estimation coefficients for the variable *DTNM* also indicate that proximity to the nearest wet market or supermarket is not a predictor of household dietary diversity. The signs of the estimated coefficients for the variable *DTNM* are consistent with expectations, but the estimated coefficients for the variable *DTNM* of Model IV, Model V and Model VI are statistically insignificant. The test of the mediation and suppression effects indicates that there are no effects for the variable *DTNM* and variable *SFSA,* which suggests that physical access to wet markets or supermarkets is not a determinant of household dietary diversity. Thus, information regarding the estimated coefficients of the variables *DTWM*, *DTSM* and *DTNM* indicates that proximity to wet markets and supermarkets is not a predictor or determinant of urban household dietary diversity. In other words, the difference in the distance to wet markets or supermarkets makes no difference to urban household dietary diversity in Nanjing.

Implications for Dietary Diversity

Wet Market Planning Policies

The insignificant statistical correlation between the distance to the nearest market and household dietary diversity in Nanjing does not necessarily mean that proximity to food outlets is not important for residents' access to diverse food items. It is therefore important to understand the underlying reasons for the insignificant correlation. The most important is that the food infrastructure development planning in Nanjing has led to relatively equal and convenient access to wet markets or supermarkets for all households. This relates to the "mayor responsible for vegetable basket" system launched by the Chinese central government in 1988.

The system makes mayors responsible for promoting the production of and securing the supply of non-grain food (Ge et al 1992). The mandatory system has ensured an extensive food supply network in Nanjing, and is the foundation for the high level of physical accessibility to food. Accessibility was further enhanced by the Development Plan for Vegetable Basket Project (2008-2012) issued by the Nanjing Municipal Government in 2008, which specifies that the construction of wet markets should be strengthened (Nanjing Municipal Government 2008).

Food infrastructure, and particularly the development of wet markets, has been a requirement for the development of new residential communities in Nanjing since the early 2000s. In 2003, the Nanjing Municipal Government issued regulations on wet market planning and construction and a notice on implementing regulations on wet markets planning and construction, which specified that each newly developed residential community with a construction area over 50,000m^2 should construct a new wet market with an area no less than 1,000m^2 (Nanjing Municipal Government 2003a, 2003b). In 2004, the Commodity Network Plan of Nanjing City planned to have a wet market with a service radius of 500-1,000m for every 30,000 residents (Nanjing Municipal Government 2004). In 2011, the Nanjing Municipal Government updated these standards and required a wet market with an area no less than 2,000m^2 and a service radius of 500m for every 25,000 residents; and a wet market with an area no less than 1,500m^2 for each town with a population larger than 20,000 (Nanjing Municipal Government 2011). According to the Plan of Commercial Network in Nanjing (2015-2030) for Public Consultation, more than 200 new wet markets will be established in Nanjing by the year 2030 (Nanjing Urban Planning Bureau 2016).

Besides these food infrastructure planning policies, the Nanjing Municipal Government has implemented the policy of "fresh produce zones" in supermarkets. In 2011, Nanjing Municipal Government issued a policy document that required that no less than 20% of existing supermarkets' area and 30% for newly opened supermarkets should be used for fresh produce retail (Nanjing Municipal Government 2011).

The implementation of these policies regarding food market development and planning means that there is relatively easy access to wet markets and supermarkets in Nanjing. About 26%, 56%, 74% and 80% of the interviewed households had a network distance to the nearest wet market or supermarket of less than 0.5km, 1.0km, 1.5km and 2.0km respectively (Table 8). Assuming a median walking speed for an adult of 4.5km/h or 1.25m/s (Schimpl et al 2011), and a 15-minute walk as the commonly accepted walking time in food studies (Chum et al 2015, Ver Ploeg 2010), then anything up to about 1.1km is an acceptable walking distance.

About 58% of the surveyed households' walking distance to the nearest wet market or supermarket was less than 1.1km (Table 8). The average distance to the nearest wet market or supermarket was 1.2km for those households that reported buying vegetables, fruits and meat from wet markets or supermarkets. Cycling is also a popular transportation mode in Nanjing. An average speed by bicycle of 6.05km/h (Zhang 2017), would mean about 1.5km for a 15-minute ride by bicycle or 2.0km for a 20-minute ride. About 74% and 80% of the surveyed households had a cycling distance to the nearest wet market or supermarket of less than 1.5km and 2.0km, respectively.

TABLE 8: Distance from Households to the Nearest Wet Markets or Supermarkets

Distance range (m)	% of households	Distance (m, ≤)	Cumulative percent (% of household)
0-500	25.9	500	25.9
501-1,000	29.8	1,000	55.8
1,001-1,500	15.5	1,500	71.3
1,500-2,000	8.6	2,000	79.8
2,001-2,500	5.2	2,500	85.0
2,501-3,000	6.1	3,000	91.1
>3,000	8.9	≤7,303	100.0

Offsetting Effect of Small Food Stores

Another factor that contributes to the high level of physical access to food in Nanjing could be the many small food stores, including small shops and *xiao mai bu*, located within or near residential communities. The survey in 2015 shows that 35% of surveyed households buy food from small food stores and that 26% do so at least five days a week or once a week. Unfortunately, the massive number of small food stores in Nanjing makes it nearly impossible to geocode them comprehensively. However, we should not ignore the important role of small food stores in household food accessibility.

There has probably been an offsetting effect of small food stores in ensuring food diversity for households who live relatively far away from wet markets and supermarkets. A study in New Orleans found that other types of stores did offset the relative lack of supermarkets for snack foods but not fresh produce (Bodor et al 2010). The offsetting effect could also be true in Nanjing. As small food stores are close to residential communities, they could contribute to household dietary diversity in relatively underserved areas. This is a reasonable conclusion given that individual small food stores provide more than seven of the types of food included in the HDDS indicator. Additionally, the common clustering of small food stores further enhances the diversity of their supply. Unlike small stores in the US where food is more expensive compared to supermarkets and large grocery stores (Ver Ploeg 2010), supermarkets in China have no price advantage over wet markets (Zhang and Pan 2013). The primary reason is that the labour cost and food waste of the supermarket is higher than wet markets while the wholesale market is the main source of food for both supermarkets and wet markets (Zhang and Pan 2013). As the small shops can also obtain vegetables directly from peri-urban small-scale producers at lower costs than from wholesale markets, wet markets have no price advantage over small-scale stores (Zhang and Pan 2013).

Local Food Purchasing Behaviour

The high level of physical accessibility to food outlets in Nanjing is mirrored in the high proportion of households buying food in their neighbourhood or within walking distance. According to the Hungry Cities Food Purchases Matrix used in the survey (Crush and McCordic 2017), more than 90% of households said they normally buy most fresh food items within their neighbourhoods or within walking distance (Table 9). Specifically, 92-93% of households buy their fresh vegetables, fruit and pork in their neighbourhoods or within walking distance. A slightly lower percentage buy fresh animal products in their neighbourhoods or within walking distance: 89% for eggs, 88% for fresh shellfish, 86% for fresh lamb and 73% for milk.

TABLE 9: Location of Food Outlets Where Fresh Food Items Normally Purchased

Item	% beyond neighbourhood	% within neighbourhood
Fresh/cooked vegetables	7.0	93.0
Fresh pork	7.9	92.1
Fresh fruit	8.2	91.8
Fresh chicken	8.7	91.3
Offal	8.8	91.2
Fresh fish	9.2	90.8
Fresh beef	10.0	90.0
Eggs	11.5	88.5
Fresh shellfish	11.7	88.3
Fresh lamb	14.1	85.9
Milk	26.8	73.2

Note: "Within" refers to within walking distance; "beyond" refers to beyond walking distance.

More than 90% of surveyed households bought their main food items in their neighbourhoods or within walking distance. In contrast, only 58% of households were within easy walking distance (up to 1.1km) of their nearest wet market or supermarket.

The difference between 90% and 58% is 32%, which is offset by the presence of small food stores. This is further evidence that small-scale food stores contribute to access to food within neighbourhoods, in addition to their offsetting effects where households are relatively far away from wet markets and supermarkets.

Household Demographic Factors and Dietary Diversity

This study also examined the impacts of other factors (including household size, structure and income) on dietary diversity. The estimation results indicate that, unlike distances to food outlets, household size, structure, and income all significantly influence household dietary diversity (Table 7). Those coefficients of variables in Model I and Model V are statistically significant and consistent with expectations, including the variables *HHS, HHS2-HHS6, EXTD, HHIM* and *HHIH*. The coefficients for the variable *HHS* in Model I and Model V were 0.0307 and 0.0306, respectively. For an increase in household size by one, a household's mean HDDS increases by a factor of 1.03 or by 3.10%. This is also a small change considering that the mean HDDS is 7.83. The coefficients for variables *HHS2, HHS3, HHS4, HHS5* and *HHS6* are statistically significant in both Model I and Model V. There are similar coefficient values for variables *HHS2, HHS3, HHS4, HHS5* and *HHS6* in Models I and V. The coefficients for variable *HHS7, HHS8* and *HHS9* are not statistically significant in both models. This indicates that those households with 2 to 6 members have a higher HDDS than one-person households. Compared with the reference category of households with one person, multi-person households have an expected HDDS value increase of 17% (2 persons), 20% (3), 21% (4), 31% (5) and 23% (6) (based on the estimated coefficients in Model I). The variable *HHS5* has the highest coefficient among variables *HHS2-HHS6*. Due to the one-child policy, a five-person household usually means a household with one child, parents and grandparents (which is also categorized as an extended household). The co-efficients for the variable *EXTD* were 0.0825 and 0.0845 in Model III and Model VI, respectively. Being an extended household increases the value of HDDS by about 9% (8.6% and 8.8% for Model III and Model VI, respectively). This indicates that household size and household structure have a moderate impact on household dietary diversity.

Extended households are relatively common in Nanjing, making up just over one-quarter of all the surveyed households. The relatively high percentage of extended households diminishes the sensitivity of household dietary diversity to physical access to wet markets and supermarkets. Another study has indicated that household structure plays an important role in Chinese family-based food consumption (Liu 2017). Dual-career families (where both husband and wife work) are common in China. This means that it is the grandparents in extended households who buy the food and do most of the cooking and other domestic work (Liu 2017). In addition to extended households with three generations living in one dwelling, it is also common for grandparents to live in different dwellings within a short distance from the household of their adult children and grandchild and are commonly involved in the food practice of their children's households (Liu 2017). As retired grandparents in extended households have more flexibility in terms of time and food purchase location, they are less sensitive to the shopping distance than young family members who devote most of their time to work. As a result, support from grandparents could make the HDDS of extended households and some nuclear households less sensitive to the distance to wet markets and supermarkets than households without the support of grandparents.

The estimation results also suggest that some characteristics of household heads are predictors of household dietary diversity. The coefficients for the variables *HHE* and *HHM* are significantly negative.

Being a household with an unmarried household head decreases the expected HDDS by 18%, compared with other households. Being a household with a household head without formal schooling decreases the expected HDDS by 19%, compared to a household with a household head with formal schooling (calculated based on the estimated Model I). However, the coefficients for the variable *HHA* (household head age) are not statistically significant, and neither are the coefficients for the variable *HHG* (household head gender) except in Model V. This is consistent with previous studies about household dietary diversity in China (Liu et al 2014).

Household Income and Dietary Diversity

The significant positive coefficients for the variables reflecting household income and housing type (*HHIM, HHIH* and *HOUSE*) indicate that income is an important determinant of urban household dietary diversity. An increase in household income contributes to an increase in dietary diversity. Middle- and high-income households have a higher HDDS than low-income households. Being a middle-income household increases the expected HDDS by about 13% compared to a low-income household (the mean of 13.1%, 11.4%, 13%, 13.9%, 12.2% and 13.9% for Model I, Model II, Model III, Model IV, Model V and Model VI, respectively). Being a high-income household increases the value of HDDS by about 11%.

In Nanjing, three-quarters of households live in apartments, with only a small proportion (2.4%) of wealthier households living in houses. The significant positive coefficients of the variable *HOUSE* suggest that households living in houses have higher dietary diversity. This is reflected in the 21% higher HDDS of households living in houses, compared to low-income households. Other studies indicate that an increase in household income increases a household's economic access to food (Burchi and De Muro 2016).

Increased income could contribute to dietary diversity by improving a household's transport facilities and food-preserving facilities. Electric bicycles, for example, are a faster and more expensive vehicle than traditional bicycles (priced about 10 times higher). The speed limit of an electric bicycle is 20km/hour, which means that the travel distance of 10 minutes by electric bicycle is about 3km. Our spatial analysis found that more than 90% of households had a network distance to the nearest wet market or supermarket of less than 3km. The high level of food accessibility is further enhanced by the increasing popularity of private cars in Nanjing. On average, there were 59.7 electric bicycles and 40.4 private cars per 100 urban households in 2015 (Nanjing Municipal Bureau of Statistics 2016). In 2012, 10% of young adults and 1% of the aged in Nanjing shopped for food by car (Feng and Yang 2015). The prevalence of refrigerators may also contribute to dietary diversity. In 2016, there were 102.4 and 109.5 refrigerators per 100 urban and rural households, respectively (Nanjing Municipal Bureau of Statistics 2016).

Urban Agriculture and Dietary Diversity

Although the estimated coefficients for the variable *CROPPING* are positive and the signs are consistent with expectation, the coefficients are statistically insignificant. This indicates that whether households grow their own food or not does not significantly influence dietary diversity. This is simply because urban farming in Nanjing has very limited access to land and thus is unable to produce a significant quantity of food. Moreover, even in the peri-urban or rural areas, the variety of produce is constrained by the size of farms and seasonality, which does not contribute to household dietary diversity. It is even likely to negatively impact household dietary diversity for households that only consume the limited variety of food produced on their own land (Liu et al 2014).

Conclusion

This paper shows that, in contrast to studies in other contexts where proximity to food stores is one of the determinants of household dietary diversity (Koppmair et al 2017, Liu et al 2014), the distance from the household home to the nearest wet market or supermarket has no significant impact. The coefficients for the distance to the nearest wet market are not statistically significant. The coefficients for distance to the nearest supermarket are of statistical significance but not of economic significance or practical significance, as the very small coefficients indicate that distance to the nearest supermarket has no noticeable impact on household dietary diversity. However, these results do not necessarily indicate that the distance to food outlets is not important for household dietary diversity in other contexts. The high level of food accessibility due to the spatially dense food supply network in Nanjing diminishes the correlation between distance and dietary diversity. Small food stores, together with wet markets and supermarkets, have created a favourable food environment in terms of physical access to food, which in turn leads to a non-significant relationship between the proximity to wet markets or supermarkets and household dietary diversity. The spatial distribution of wet markets, supermarkets and small-scale food stores constitutes a favourable food environment in term of geographic access to food, which results in a relatively equal geographical access to food outlets. Such access decouples any linkage between the proximity to wet markets or supermarkets and household dietary diversity.

The study also found that various factors contribute to the non-significant influence of distance to the nearest wet market and supermarket. These include relatively high accessibility to food outlets, the prevalence of three-generation extended household structure, and higher household income. Extended households with three generations are less sensitive to the distance to wet markets and supermarkets because the grandparents who conduct most food practices in the households are more flexible in terms of time and food purchase location. In addition, higher household income and better transport and food-preserving capacity all contribute to the insignificance of the proximity to wet markets or supermarkets in determining urban household dietary diversity.

The implications of this study for food system management in terms of urban land use governance are twofold. First, it is important to achieve high access to food by allowing and encouraging mixed land use for food outlets within or close to residential communities. Most wet markets and supermarkets in Nanjing are located close to residential communities, and small food stores are even located within residential communities. The policies that encourage mixed land use for food outlets have greatly enhanced residents' physical access to food outlets. Second, it is important to include wet markets in urban infrastructure planning systems, and setting wet market construction as a mandatory requirement for the development plan of new residential communities can be an effective tool to improve and secure physical access to food outlets.

Acknowledgments

This research was funded by the Hungry Cities Partnership project supported by the Social Sciences and Humanities Research Council of Canada and the International Development Research Centre through the International Partnerships for Sustainable Societies (IPaSS) Program.

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